Difficulties and limitations in minimally invasive repair of pectus excavatum — 6 years experiences with Nuss technique

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Received 22 April 2006; received in revised form 30 July 2006; accepted 7 August 2006; Available online 18 September 2006

Abstract

Objective: In 1998, Dr Donald Nuss proposed minimally invasive repair of pectus excavatum (MIRPE) which did not require the osteochondrous parts of the anterior chest wall to be resected. The paper aims at presenting the authors’ own 6 years of experience in funnel chest repair with MIRPE technique. Also, many technical problems of this method are discussed.

Materials and methods: Between 1999 and 2005, 461 patients (99 female and 362 male, aged 3–31 years, mean age 15.2 years) with pectus excavatum were operated with the Nuss technique. All patients were operated on according to the original operative protocol proposed by Donald Nuss. With growing experience, own modifications were introduced. Insertion of two bars was done in 17.4%, transverse sternotomy in adolescents with rigid anterior chest wall in 7.8%, limited excision of the rib cartilages in 5.9%, and parasternal fixation of the bar to prevent it from rotating in 59.7% of patients.

Results: There were no deaths. Intraoperative complications were noted in 19 (4.1%) patients and postoperative ones were observed in 43 (9.3%) patients. The operative time ranged from 25 to 130 min (52 min on average). In 192 (41.6%) patients, an epidural block was used. The hospital stay ranged from 4 to 12 days with the mean of 5.3 days. A redo procedure for the bar rotation was necessary in 13 (2.8%) patients. The support bar has been removed in 260 (56.4%) patients so far. In all the patients, an adequate contour of the anterior chest wall has been maintained.

Conclusions: MIRPE proposed by Nuss has all the features of a minimally invasive procedure and is straightforward. Better clinical results are achievable in patients under 12 years of age with a symmetric deformity. In older patients (over 15 years of age) with a rigid chest or with an asymmetric deformity, additional procedures are required to achieve a comprehensive correction of the deformity. Recent results and forward clinical observations may give proof to establish MIRPE as a method of choice in funnel chest correction.

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Keywords: Chest wall; Pectus excavatum; Minimally invasive surgery
All patients were operated on according to the original operative protocol proposed by Donald Nuss. With growing experience we introduced our own modifications which are as follows:

- transverse sternotomy in adolescents with rigid anterior chest wall to reduce tension and pressure from the bar to the rib cage;
- limited excision of the rib cartilages in patients with asymmetric deformity, considerable sternal rotation and unilateral bulging of the parasternal rib segments;
- parasternal fixation of the bar (a stitch embracing the bar and adjacent rib inserted with the use of a laparoscopic fascial needle) to prevent it from rotating.

Factors considered in the assessment of the surgical outcomes were as follows: indication for the repair, diagnostic studies results, operative technique including own modifications, duration of the procedure, hospital stay, complications, short-term results, and long-term follow-up after the bar removal.

3. Results

The most important factor in qualifying the patients for funnel chest repair was the cosmetic aspect of the defect (99% of the patients). Two hundred and thirty four (50.8%) of the operated patients, however, had a history of exertion intolerance and fatigability in relation to their peers.

EKG abnormalities, including cardiac axis deviation and abnormal repolarization, were observed in 290 (62.9%) patients. Mitral valve prolapse was seen in 272 (59%) patients. Pulmonary function tests predominantly revealed a restrictive pattern which was encountered in 178 (38.6%) patients.

CT of the chest was used for determining the severity of deformity according to Index Pectus (IP)—Table 1.

The type of deformity was classified based on physical examination and CT scan analysis. There were 250 (54.2%) symmetric, 171 (37.1%) asymmetric with sternal rotation, and 40 (8.7%) mixed with flat or pigeon chest deformities.

Additional surgical procedures performed during funnel chest repair are listed in Table 2.

Transverse sternotomy and insertion of a second bar were carried out mainly in older patients over 12 years of age with a considerably rigid anterior chest wall. The resection of rib cartilages was done in older patients with an asymmetric deformity. Initially, lateral stabilizing bars were used in six patients to prevent the support bar from rotating. Our own method of parasternal fixation of the bar was implemented in July 2000.

Intraoperative complications were noted in 19 (4.1%) patients and postoperative ones were observed in 43 (9.3%) patients (Table 3). Nine patients were admitted to the hospital during early postoperative period—four for pericardiac serous exudate and five for pneumonia and pleurisy. A redo procedure for the bar rotation was necessary in 13 (2.8%) patients. In four of them the bar position was corrected and in nine the bar was removed and replaced with a new one.

The operative time ranged from 25 to 130 min (52 min on average). In 192 (41.6%) patients an epidural block (Fentanyl, Marcain) was used over five consecutive postoperative days. In the remaining patients postoperative pain was controlled with a combination of drugs (ketonal, morphine, amizepine). The hospital stay ranged from 4 to 12 days with a mean of 5.3 days.

The support bar has been removed in 260 (56.4%) patients so far. Bar removal was done after 26 months on average (range from 22 to 32 months). In all the patients, an adequate contour of the anterior chest wall has been maintained. Additional excision of excessively protruding rib cartilages was performed during the bar removal procedure in 15 (3.3%) patients.

### Table 1
The severity of deformity based on IP

<table>
<thead>
<tr>
<th>IP</th>
<th>Number of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3.25</td>
<td>139 (30.2)</td>
</tr>
<tr>
<td>3.26–4.0</td>
<td>222 (48.1)</td>
</tr>
<tr>
<td>&gt;4.0</td>
<td>100 (21.7)</td>
</tr>
</tbody>
</table>

### Table 2
Additional procedures performed during funnel chest repair

<table>
<thead>
<tr>
<th>Additional procedure</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion of two bars</td>
<td>80 (17.4)</td>
</tr>
<tr>
<td>Transverse sternotomy</td>
<td>36 (7.8)</td>
</tr>
<tr>
<td>Resection of rib cartilages</td>
<td>27 (5.9)</td>
</tr>
<tr>
<td>Stabilizer</td>
<td>6 (1.3)</td>
</tr>
<tr>
<td>Parasternal fixation of the bar</td>
<td>275 (59.7)</td>
</tr>
</tbody>
</table>

### Table 3
Complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoperative</td>
<td></td>
</tr>
<tr>
<td>Damage to the pericardium</td>
<td>4</td>
</tr>
<tr>
<td>Fracture of the sternum</td>
<td>1</td>
</tr>
<tr>
<td>Tear of an intercostals space</td>
<td>14</td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
</tr>
<tr>
<td>Persistent pneumothorax</td>
<td>7</td>
</tr>
<tr>
<td>Bar rotation&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wound infection</td>
<td>8</td>
</tr>
<tr>
<td>Pericarditis with fluid in pericardial sack&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pleuritis exsudativa and/or pneumonia</td>
<td>10</td>
</tr>
</tbody>
</table>

<sup>a</sup> Before 2000.
<sup>b</sup> One patient required pericardiocentesis.
4. Discussion

The main indication to surgical correction of the pectus excavatum is cosmetic defect. In literature discreet cardiopulmonary disorders and decreasing effort tolerance are emphasised [9–11]. In our material, changes in electrocardiography and ultrasound examination of the heart were recognized in 60% of the patients and changes in spirometry in 38% of the patients.

Until recently, many problems related to surgery for funnel chest have been disputable. These included the timing and indications for surgery, the way of maintaining the correction, and even the method and range of rib cartilage resection [1,3,4]. The selection of patients for a particular corrective procedure often depended on personal experience of the surgeon. No existing method has been considered an ideal solution as long-term follow-up showed that late correction, and even the method and range of rib cartilage resection [1,3,4]. The selection of patients for a particular corrective procedure often depended on personal experience of the surgeon. No existing method has been considered an ideal solution as long-term follow-up showed that late destruction might be considerable [12,13]. MIRPE introduced by Donald Nuss makes the problem easier. No bony structure is resected or even transacted. Indications for surgery have widened. In our group, 30% of patients were qualified for surgery with smaller deformity (IP < 3.25).

The correction is achieved by making the ribs grow along the contour established by the bar. The advantages of the method are mainly visible in younger patients (up to 12 years of age) with a soft and malleable chest and with no permanent asymmetric rigid deformity of the anterior chest wall. In our clinical material, older patients (over 12 years of age) were predominant (79%). There were 18.2% of patients who were over 18 years of age. This was because of their late referral to our department. The delay resulted from the common conviction based on the experience derived from the Ravitch technique that best results could be achieved in adolescents (teenagers). In 70% of the operated patients, the deformity was significant (IP > 3.25) and in 37%, asymmetric. Both advanced age of the patients and considerable asymmetry of the deformity caused difficulties in correcting the anterior chest wall deformity [14–16]. Therefore, additional procedures were necessary to achieve and maintain an adequate correction. The insertion of the second bar in 80 patients made sternal elevation more effective and allowed for better force distribution. However, sometimes the bar tears intercostal muscles in patients with a stiff anterior chest wall and this was the case in 14 of our patients. Therefore, transverse sternal osteotomy through additional small incisions was performed in 36 (7.8%) patients to reduce sternal rigidity and its pressure on the bar. The transverse sternal osteotomy (wedge osteotomy) was made on sternum shaft in place of the biggest sternal deflection similar to Ravitch technique. In patients presenting with a considerable asymmetric deformation and sternal rotation, a bilateral resection of the rib cartilages at the level of the greatest rotation is often necessary—in 27 (5.9%) patients. In patients under 12 years of age, chest wall is very flexible and accurate shape can be easily achieved with one bar even in case of asymmetry. The procedure is easier, less time-consuming, and risk of complications is very low. Only two children under 12 years of age needed additional procedures (one second bar insertion and one resection of rib cartilages).

One of the problems associated with MIRPE reported in the literature is the bar rotation in the postoperative period. The recommended use of the lateral stabilizers has not proved to be always effective. The procedure provides stronger fixation of the support bar at its ends, but does not prevent the bar from rotating and is associated with more extensive dissection and stronger inflammatory process at the ends of the bar [17]. It also makes the bar removal more difficult. Some authors advise bar fixation to the rib on both sides with surgical wire [18]. In 2000, we introduced our own method of parasternal fixation of the bar to the adjacent rib, which seems to be effective. Since then we have noticed no bar rotation. The method has been approved by other authors [19].

Considering our experience in videosurgery, we performed thoracoscopy in all patients while introducing MIRPE to control the passing of the Kelly clamp and the support bar between the posterior aspect of the sternum and the pericardium. Initially, Donald Nuss performed the procedure without thoracoscopic guidance but later on decided to carry out thoracoscopy on a regular basis.

We believe that MIRPE performed under thoracoscopic guidance is safer. Despite the routine use of thoracoscopy we did not avert small damage to the pericardium in four of our patients. This probably would not have been noticed if the procedure had not been performed under thoracoscopic guidance. Excessive sternal elevation due to its fracture observed in the youngest of the children was also reported by the author of MIRPE but such deformity tends to resolve spontaneously with time.

Postoperative complications reported by other authors occurred also in our patients [20–22]. Postoperative wound infections were observed in eight patients and pneumonia or pleuritis in another 10. Persistent pneumothorax in six patients occurred at the early period of the use of the method, as we did not introduce a chest tube for 24 h postoperatively (first 21 patients). Four cases of fluid collection in the pericardium (one of them required aspiration, three resolved spontaneously) were associated with no evidence of infection and pericarditis. This suggests reactive chemical pericarditis caused by the bar.

Dealing with postoperative pain is a real challenge mainly in older patients with a rigid chest. An epidural block helps to alleviate the pain in the immediate postoperative period [23,24]. However, many patients complain of persistent pain even several weeks after the surgery. That calls for a strict treatment program to be worked out. In our department the epidural block was performed in 192 (41.6%) patients; in the remaining patients a combination of analgesics and sedatives was used with good effects.

The duration of MIRPE in patients with a symmetric deformity and a pliable chest did not exceed 30–40 min. When insertion of two bars, sternal osteotomy or rib cartilage resection (in combination or alone) was necessary, the operative time lengthened up to 130 min. The advantages of MIRPE are short hospital stay and a very good long-term cosmetic result.

The problem of bar removal has seldom been raised in the literature so far [25]. In our experience based on 260 (56.4% of all operated) cases the removal may be a difficult and time-consuming procedure, especially in patients who have grown considerably during two years of living with the bar. The rigid steel bar exerts pressure over the growing ribs provoking profound osteotylus formation at its ends. In these cases, the bar removal is associated with at least partial osteotylus resection. Often the bar penetrates into the
intercostals space, making its removal still more difficult. Therefore, in younger patients, in whom rapid growth was anticipated over two years following surgery, the bar was curved so as to leave bilateral space of 1 cm between the ends of the bar and the chest wall.

MIRPE allows for even slight and moderate deformities to be corrected. In 30.2% of the patients, IP was below 3.25. MIRPE is a very valuable procedure for treating younger patients less than 12 years of age. In older ones, it often has to be combined with additional procedures within the anterior chest wall. Therefore we feel that the procedure should be performed by surgeons who have considerable experience in dealing with funnel chest and are equipped with thoracoscopic facility.

5. Conclusions
1. MIRPE proposed by Nuss has all the features of a minimally invasive procedure and is straightforward.
2. The better cosmetic results are achievable in patients under 12 years of age, even in case with asymmetric and mixed deformities.
3. In older patients (over 15 years of age) with a rigid chest or with an asymmetric deformity, additional procedures are required to achieve a comprehensive correction of the deformity.
4. Recent results and forward clinical observations may give proof to establish MIRPE as a method of choice in funnel chest correction.

References